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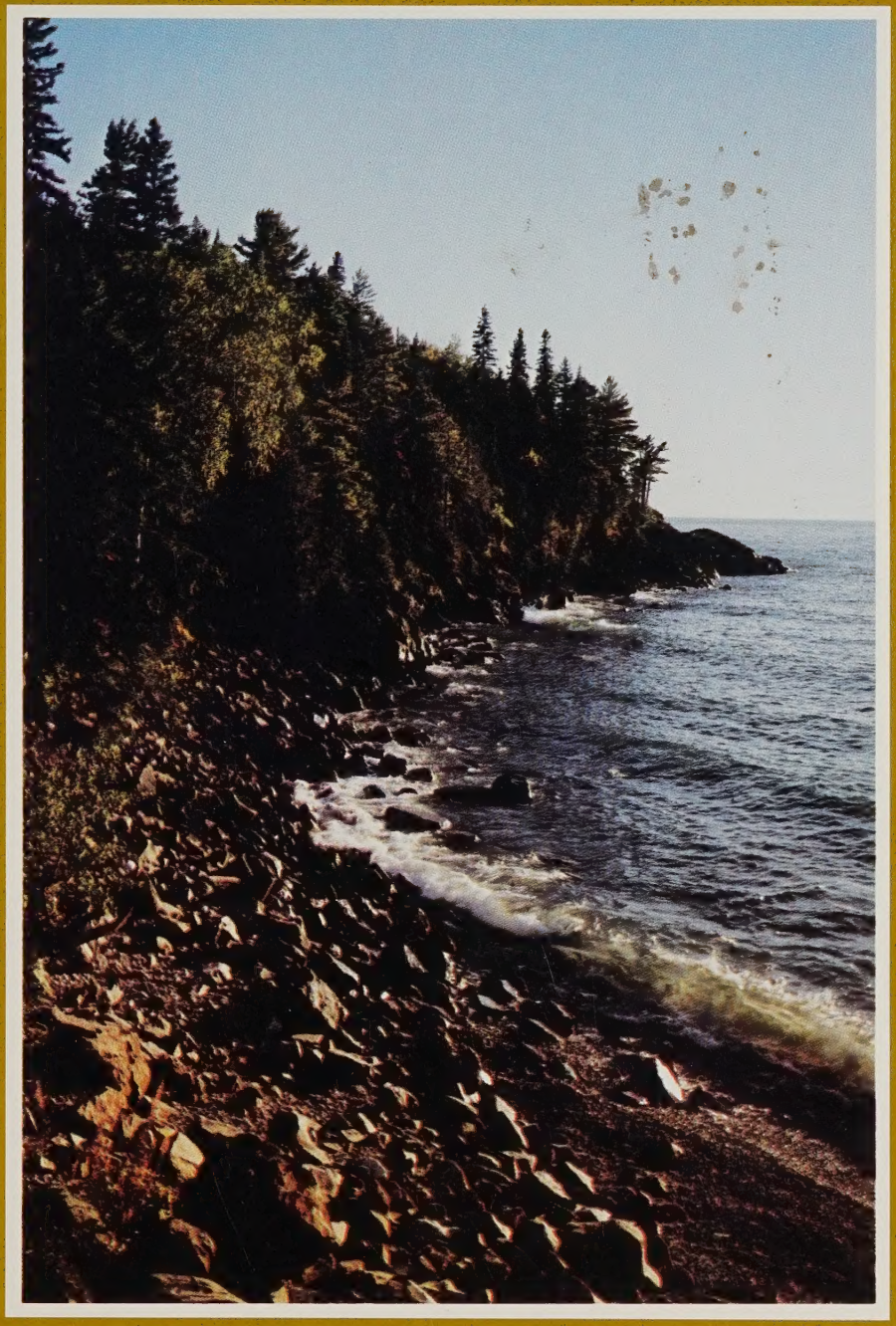
The Great Lakes

Walter M. Tovell



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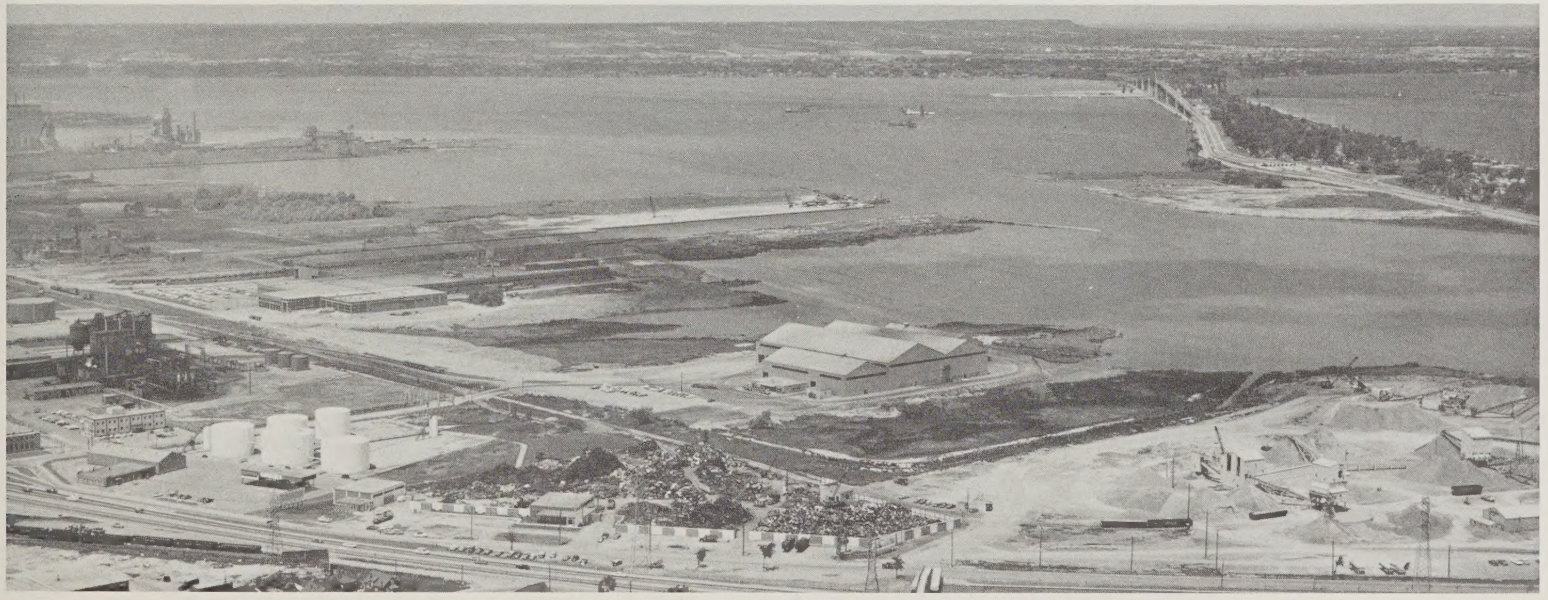
A vital resource

The Great Lakes comprise 20 per cent of the world's most important natural resource—fresh, surface, liquid water, enough of it to cover the entire North American continent to a depth of about a metre. Easy access to this natural resource has attracted heavy settlement to the shores of the lakes and today 33 per cent of the population of Canada and 14 per cent of that of the United States—37 million people in all—live clustered around them.

For a clear understanding of the Great Lakes, we must know where they are, how they got there, and what is happening to them. Only then can we devise sound and workable plans for preserving this vital resource.

The shorelines of the Great Lakes present a variety of scenery: rocky headlands, forested slopes, eroding bluffs, and beaches bordered by sand dunes. In many bays, usually occurring where rivers and streams enter the lakes, are to be found marshes which provide a rich wildlife habitat. Along the shores, orchards, farmlands, factories, and electrical generating stations reflect the land use of the region.

However, the land use in the individual lake basins varies. For example, 95 per cent of the land in the Superior basin is still classed as forest-woodland, while in both the Erie basin and the Ontario basin much of the land is devoted to agriculture—32 per cent in the former and 59 per cent in the latter. Urban and industrial centres comprise 4 per cent of the land area of the Ontario basin and the Michigan basin, and 9 per cent of the Erie basin.



The growth of industrial complexes and harbour facilities such as Hamilton Harbour is gradually changing the land use pattern in the Great Lakes basin.

Figure 1 Great Lakes-St. Lawrence River drainage basin.

Where are the lakes?

The Great Lakes occur in a basin that covers an area of 767 000 km^2. The basin lies astride the international boundary between Canada and the United States, and extends from 40°30′ to 50°30′ north latitude and from 74°30′ to 93°10′ west longitude. Five major lakes—Superior, Michigan, Huron, Erie, and Ontario—occupy 32 per cent of the area and are among the 15 largest lakes in the world; in fact, Lake Superior is the largest body of fresh water on earth (Figure 1). The deepest parts of four of the lakes—Superior, Michigan, Huron, and Ontario—extend below sea level (Figure 2).

Lake St. Clair is a small, shallow lake between Lake Huron and Lake Erie. Lake Nipigon, Lake Simcoe, and Lake Nipissing are other important lakes within the Great Lakes basin, whose origins are closely tied to those of the major lakes.

The drainage system The Great Lakes are connected by a series of large rivers whose flows are relatively constant in comparison with fluctuations in other rivers of similar size, such as the Fraser and the North Saskatchewan. All the waters of the system, beginning with Lake Superior, drain through the St. Lawrence River to the Atlantic Ocean. More than half of the drop from Lake Superior (elevation 183 m) to sea level occurs on the Niagara River between Lake Erie (elevation 174 m) and Lake Ontario (elevation 74 m).

Geological setting All the Great Lakes except Lake Superior lie just south of the contact between the Precambrian rocks of the Canadian Shield and the Palaeozoic sedimentary rocks of the Interior Lowlands. The Precambrian rocks form the Laurentian Uplands, which occupy the northern third of the Great Lakes basin. The Palaeozoic rocks underlie the Appalachian Plateau and the Interior Lowlands, of which the Niagara Escarpment is a major feature (Figure 3).

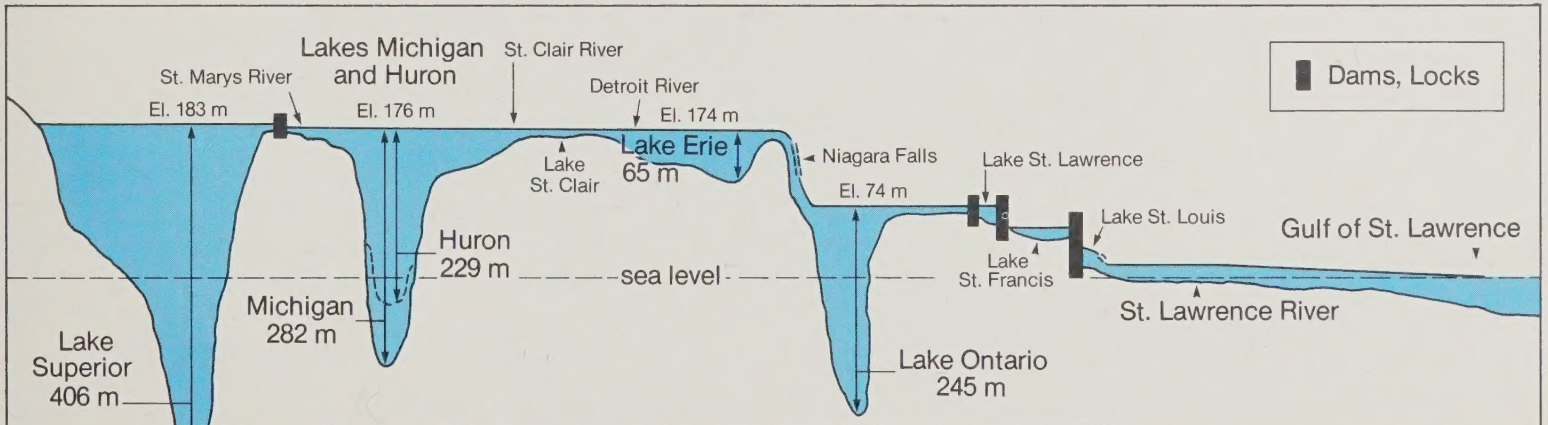


Figure 2 Diagrammatic profile of the Great Lakes-St. Lawrence River drainage basin, showing elevations and maximum depths of the lakes.

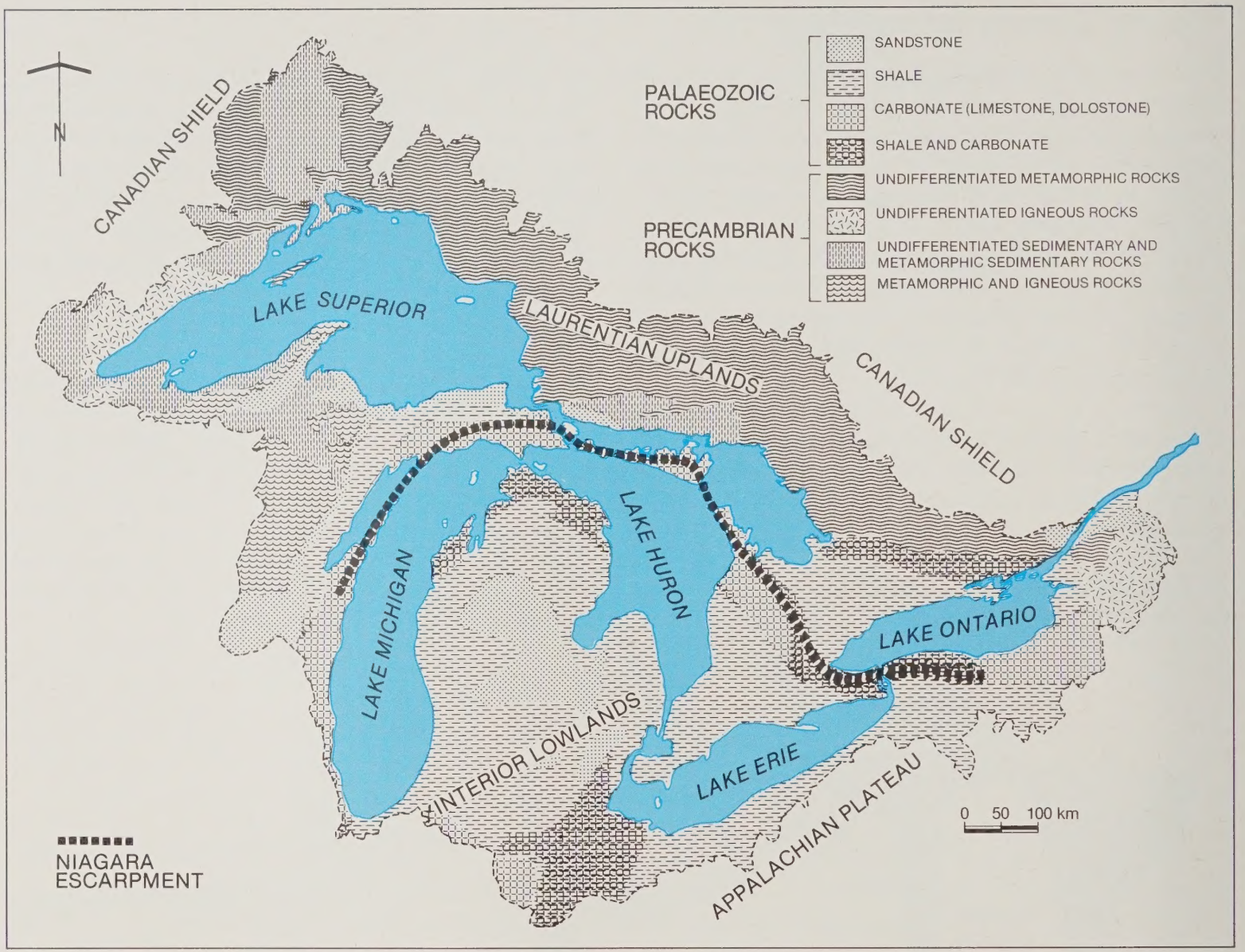
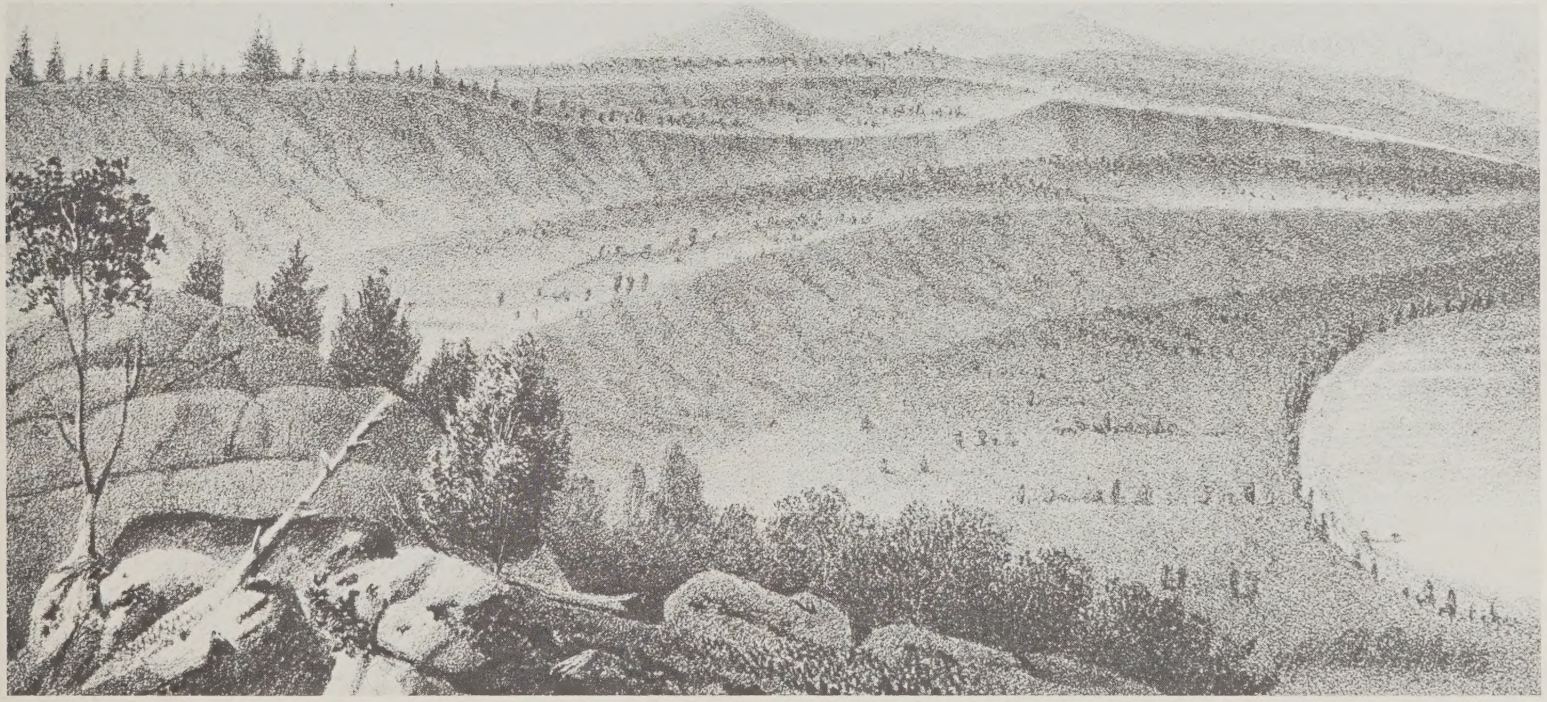


Figure 3 Generalized map of the Great Lakes basin showing the distribution of rock types in the bedrock immediately beneath the unconsolidated glacial deposits. (After *Great Lakes Basin Framework Study—Appendix 4,* Great Lakes Basin Commission.)

The origin of the lakes

Early investigations From an early date the great accumulations of fresh water in the lakes, their origin, and the fauna and flora they support attracted the attention of scientists. One of the first expeditions to investigate Lake Superior was undertaken by a group from Harvard University under the leadership of Professor Louis Agassiz. Before leaving Europe for North America, Agassiz had studied Alpine glaciers and the surrounding territory and as a result in 1837 he proposed the concept of an "Ice Age". The expedition to Lake Superior gave him the opportunity to confirm that an extensive Ice Age had existed in North America as well.

On August 3, 1848, Agassiz and his group were camped on the shores of Lake Superior near the present site of Terrace Bay, where seven terraces extend back from the shore. As he studied the terraces, Agassiz commented: "The first question is whether the lake was anciently higher; the elevation of the terraces being the same as now; or whether the land has been elevated." Before very long geologists were able to identify terraces around the other Great Lakes as the shorelines of a *series* of ancestral lakes associated with the Ice Age, that is, the continental glaciation of the Pleistocene Epoch (Table 1).



Terraces on the shore of Lake Superior near the present site of Terrace Bay. (Lithograph by J. Elliot Cabot from L. Agassiz, *Lake Superior,* 1850.)

Table 1 Geological Time Scale
The Calendar of Earth History

EON	ERA	PERIOD	BEGAN MILLION YEARS AGO
PHANEROZOIC	**Cenozoic**	Quaternary — Recent, Pleistocene	2
		Tertiary	65
	Mesozoic	Cretaceous	136
		Jurassic	190
		Triassic	225
	Palaeozoic	Permian	280
		Pennsylvanian	325
		Mississippian	345
		Devonian	395
		Silurian	430
		Ordovician	500
		Cambrian	570
PRECAMBRIAN			3700±
Formation of crustal rocks			
Origin of the earth			4600±

How they were formed Over the last quarter of the 19th century, the Great Lakes were the focus of much of the geological research in eastern North America. The shorelines of the ancestral lakes were surveyed, identified, and correlated. The work culminated in 1915, when the United States Geological Survey published the monumental history of the Great Lakes by geologists F. Leverett and F. B. Taylor. Then about 1950 investigation of the lakes was renewed, with research vessels employed to expand the information gained from land-based studies. Updated histories were published by J. L. Hough (1958) and V. K. Prest (1970).

A fairly clear picture of the development of the Great Lakes has emerged from this research. Sometime between one and two million years ago, climatic changes permitted the development of flowing glaciers on a continental scale. During the Pleistocene Epoch thousands of cubic kilometres of ice covered the northern part of North America. There were four advances and four retreats of the glaciers. While little is known about what took place in the area of the present Great Lakes in the course of the first three glacial advances and the intervening withdrawals, the fourth advance, the Wisconsinan, and its final retreat are well documented.

During the Wisconsinan advance, the glaciers divided into four lobes as they reached the Great Lakes basin. These lobes followed the basins of Lake Superior, Lake Michigan, Lake Huron, and Lake Ontario, with the Ontario lobe extending into the Erie basin. The Lake Simcoe lowlands were covered by ice that advanced from the northeast and out of the Georgian Bay basin.

In the course of the glacial advance, clays, sands, gravels, and boulders were picked up and transported in the ice. Some of these materials were deposited at the margins of the lobes in the form of irregular, hummocky ridges called *moraines*. The pattern of moraines around

Research vessel CSS *Limnos* operated by Fisheries and Oceans Canada and berthed at the Canada Centre for Inland Waters, Burlington, Ontario.

the basins of the individual lakes (Figure 4) is evidence for the lobate form of the Wisconsinan glacial advance, and in all probability the earlier glaciations followed similar patterns.

The origin of the deep lake basins that controlled the lobate character of the glacial advance is still uncertain. It has been suggested that following the withdrawal of the seas from this part of North America towards the end of the Palaeozoic era (Table 1), large master river valleys were eroded into softer rocks during the Mesozoic and Cenozoic eras. This idea was advanced because the bedrock basins of Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario are formed for the most part in shale or rocks closely related to shale. Some geologists believe that the preglacial rivers flowed towards the Atlantic Ocean, while others believe that the drainage was directed into the Mississippi valley.

The preglacial valleys were modified by the glacial advances, and the deep basins that developed trapped the meltwaters of the waning Wisconsinan glaciers. In other words, it was the waters of the Wisconsinan glaciers that initiated the evolution of the Great Lakes as we know them today. The earliest lakes were *proglacial*, so named because a segment of their shores was glacial ice.

The first to form were Lake Maumee at the southwestern end of the Lake Erie basin and Lake Chicago at the southern end of the present Lake Michigan. These bodies of water drained into the Mississippi valley. As the glaciers withdrew, the two lakes expanded, and others formed in other basins. At

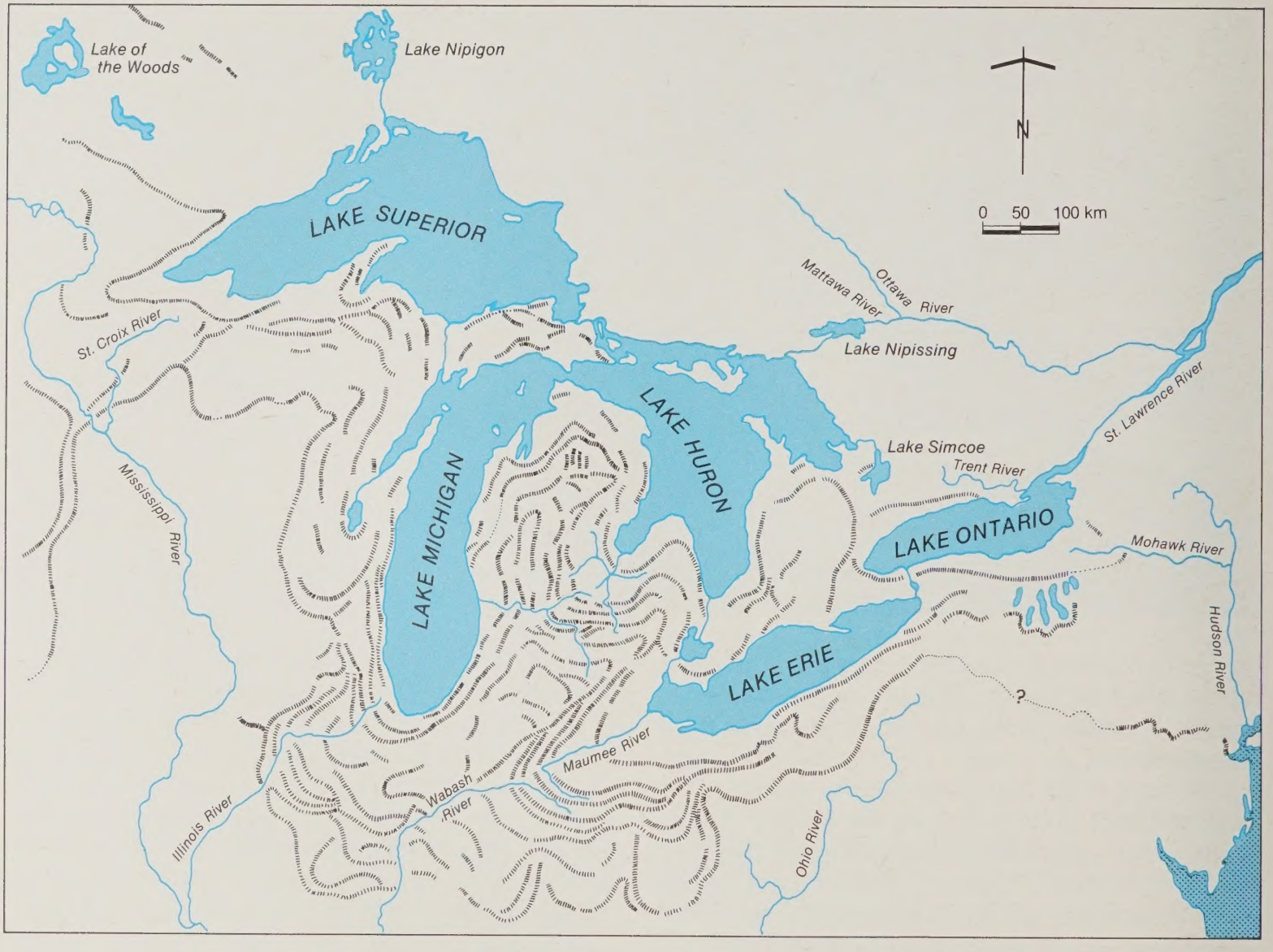


Figure 4 Principal Wisconsinan moraines of the Great Lakes basin. Notice how the pattern of the moraines parallels the outlines of the lake basins.

Glacial grooves that were cut into the bedrock by a flowing glacier loaded with boulders. South Baymouth, Manitoulin Island, Lake Huron.

The bluff marking the shoreline of ancestral Nipissing Great Lakes on Leigh's Bay Road, Sault Ste. Marie, Ontario.

times the ice readvanced locally, a fact that complicates the interpretation of the evolution of the lakes. Changes in the position of the ice front were accompanied by changes in the outlets. In the course of the evolution of the present Great Lakes, the discharge of the waters was gradually directed into the Atlantic Ocean.

Collecting the evidence Unravelling the history of the Great Lakes began with the identification and tracing of the shorelines of the ancestral lakes. Mapping of the proglacial shorelines within an individual lake basin, and from basin to basin, established the shapes and sequence of the old lakes. By 1888 it was recognized that the

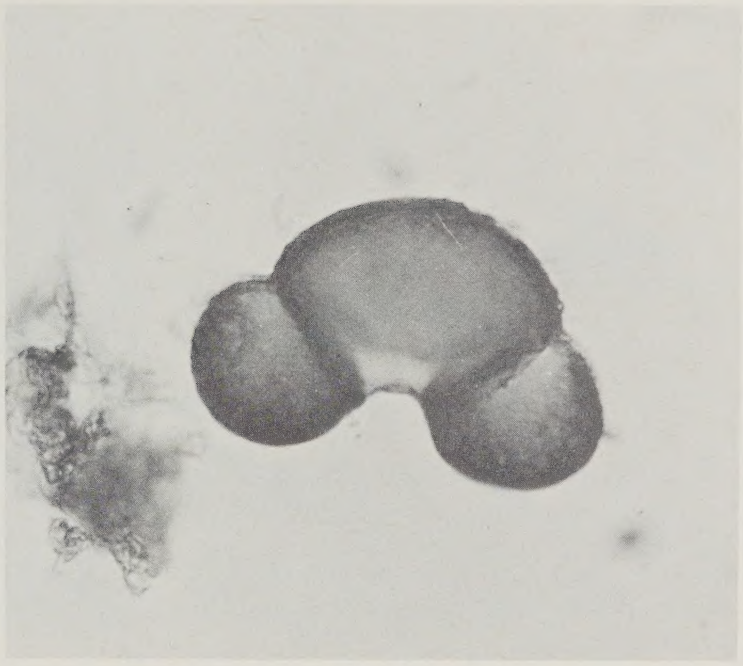
Figure 5 Elevations of the shoreline of proglacial Lake Iroquois at selected points around Lake Ontario.

shoreline of each of the old lakes no longer formed a level plane, a surprising discovery since during the existence of a proglacial lake the shoreline must have been level (Figure 5). The answer was that the crust of the earth had tilted. Thus the ever-changing geographic features of the ancestral lakes were related not only to the shifting positions of the ice front and the upland features surrounding each lake basin, but also to crustal tilting. These were the factors that controlled the water levels in each lake and dictated the outlets.

The old shorelines, which are back from and higher than the present ones, reveal that the older lakes were larger and deeper than the present ones. However, geophysical surveys of the lake basins and coring of the bottom sediments prove that smaller, shallower lakes also existed at certain times.

Dating techniques The history of a lake basin can also be determined from the sediments on its floor, and the stages of the lake can be dated by the Carbon-14 method. Carbon-14 is a radioactive form (isotope) of carbon occurring in all living matter, which can be used to date deposits containing fossilized wood and plant fragments, shells, and bones. Since Carbon-14 decays rapidly, dates are generally considered reliable only up to about 40 000 years ago.

Fossil plant pollen also occurs in lake sediment, and



On the left is a spruce pollen grain, and on the right a pine pollen grain, both 1000 times actual size.

can be extracted from it. The proportion of each plant species represented by the pollen grains is plotted on a diagram and diagrams for different parts of a lake are compared. When the information from pollen diagrams is coupled with Carbon-14 data, the history of a lake basin can be determined. In this way an absolute chronology has been established for the Great Lakes.

Phases of evolution The evolution of each of the Great Lakes from an ancestral lake to the present one can be divided into two distinct phases. The first is the time during which proglacial lakes were present, that is, the time when the shape of the lakes was controlled primarily by the receding glaciers. This period began about 14 000 years ago in the Erie and Michigan basins. The second phase began in the Erie and Ontario basins between 11 000 and 12 000 years ago and in the upper lake basins about 10 500 years ago. During this time the shape of the lakes was controlled almost entirely by crustal tilting.

It is generally believed that crustal tilting, technically known as *isostatic rebound*, occurred because the glaciers were thick and therefore heavy enough to depress the earth's crust. When they melted away, the crust rebounded, with the northeastern part of North America rising in relation to the southern limits of the Great Lakes basin (Figure 5).

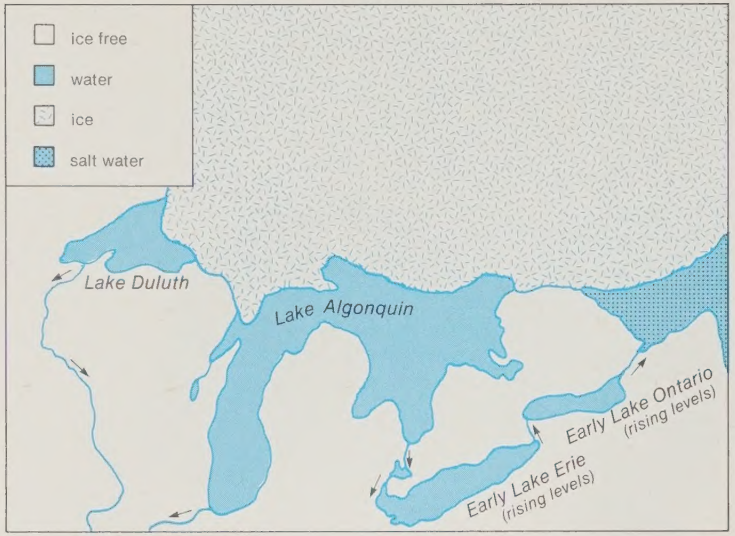


Figure 6 Outline of the Great Lakes about 11 500 years ago. Arrows indicate the direction of drainage. (After V. K. Prest, *Quaternary Geology of Canada,* 1970.)

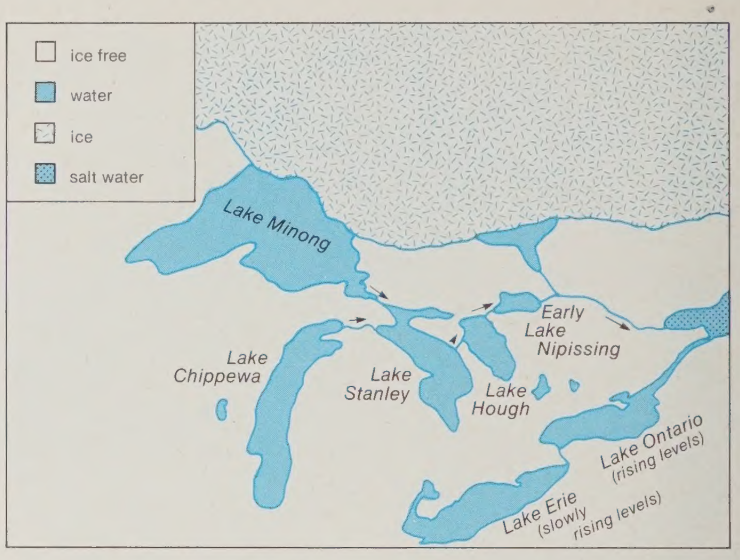


Figure 7 Outline of the Great Lakes about 10 000 years ago. Arrows indicate the direction of drainage. (After V. K. Prest, *Quaternary Geology of Canada,* 1970.)

Low-level lakes Today the natural outlet for the waters of the Great Lakes is through the St. Lawrence valley to the Atlantic Ocean. Drainage by this route began about 11 000 years ago when the Wisconsinan glaciers withdrew from the valley, opening a new outlet for the waters in the Lake Ontario basin. At that time a lake about half the size of the present Lake Ontario came into being. From this low-level stage, known as the Admiralty Stage, the waters rose and expanded to their present level as crustal tilting raised the eastern end of the lake basin.

While the lake was expanding in the Ontario basin, ice still covered the North Bay-Mattawa region. When the ice withdrew from this region about 10 500 years ago, Lake Algonquin, which occupied the basins of Lake Michigan, Lake Huron, and Georgian Bay, began to flow into the Ottawa valley, via what is called the North Bay outlet. At this time separate, low-level lakes called Lake Chippewa, Lake Stanley, and Lake Hough developed in the basins of Lake Michigan, Lake Huron, and Georgian Bay (Figures 6 and 7).

Crustal uplift of the North Bay-Mattawa region gradually caused the levels of these small lakes to rise. By about 5500 years ago they had expanded into one large lake occupying the entire basin of the upper lakes. This lake is called the Nipissing Great Lakes and its shorelines can be recognized in many areas. The drainage of all of the Great Lakes down the St. Lawrence valley became established after the North Bay outlet ceased to function and Nipissing Great Lakes fell to the levels of the present lakes. However, during this period the waters of the upper lakes drained for a short time into the Mississippi valley.

Ancestral boulder beach (67 m above Lake Superior) associated with a late stage in the development of Lake Superior. It is located on Highway 17 at Montreal River Harbour, 95 km north of Sault Ste. Marie.

A present-day beach composed of cobbles, boulders, and pebbles backed by a shore cliff, on the east shore of Lake Superior. Agawa Bay, Montreal River Harbour.

What is happening today?

Evidence for crustal tilting Since we know that crustal uplift of the Great Lakes basin has been going on over the last 12 000 years or more, it is logical to ask whether it is still going on and if so at what rate. The answer can be found in an analysis of the records of water levels of the individual Great Lakes obtained from gauges placed at 51 localities around the lake shores, some of them as early as 1860.

A lake-level gauge in its simplest form is a graduated board placed in the water and fastened to a fixed structure related to a stable benchmark on land. Modern forms are housed in stone and concrete structures and are self-recording, with lake levels recorded in metres above sea level. Except under unusual climatic conditions, the surface of a lake is level and there should be no difference between any two gauge readings from year to year. However, records from certain pairs of stations over a period of years are found to differ by ever-increasing amounts. These differences indicate that the benchmarks are moving in relation to each other, proof that the crust of the earth is tilting. Table 2 gives selected examples of the rates of tilting calculated by this method.

Fluctuating lake levels The analysis of the data from the gauges also demonstrates fluctuations in the levels of the lakes that have nothing to do with crustal tilting. They are of two types: those that vary from gauge to gauge in a given lake, and those that are constant within a given lake. The first type reflects a surging of lake waters from one part of a lake to another, while the second indicates a change in the volume of water within a lake.

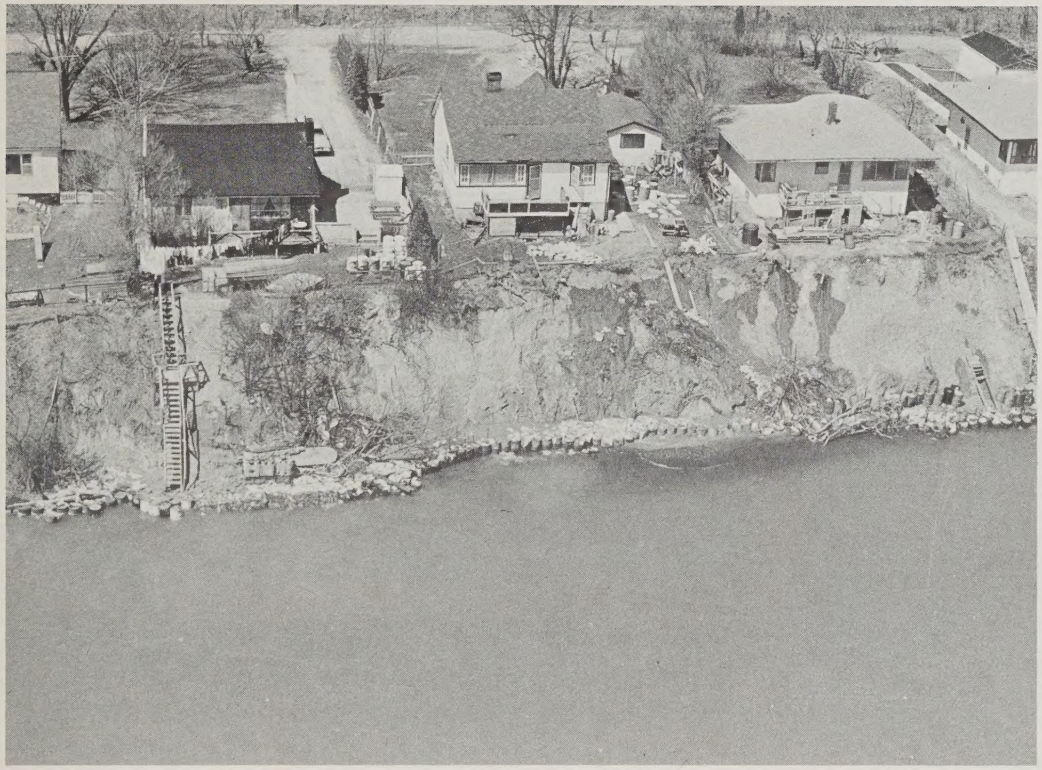
The surging is temporary and is caused by winds that blow along the long axis of a lake and drive the waters to one end; it may also be caused by differences in atmospheric pressure over different parts of a lake. Extreme examples of surging occur on Lake Erie, in part because of its position in relation to wind directions and

Table 2 Some Rates of Crustal Tilting in the Great Lakes Basin

LAKE	FIRST STATION	SECOND STATION	RATE MM/CENTURY
Ontario	Toronto	Kingston*	174
	Toronto	Oswego	94
	Oswego	Kingston	79
Erie	Cleveland	Buffalo	58
Michigan-Huron	Chicago	Thessalon	314
	Collingwood**	Thessalon	0
	Goderich	Collingwood	204
	Milwaukee	Collingwood	363
Superior	Sault Ste. Marie	Michipicoten	290
	Thunder Bay	Michipicoten	232
	Duluth	Michipicoten	521

*The second station is rising in relation to the first at the rate shown. For example, Kingston is rising in relation to Toronto at the rate of 174 mm/century.

**Collingwood is on Georgian Bay, which is part of the Michigan-Huron water plane.



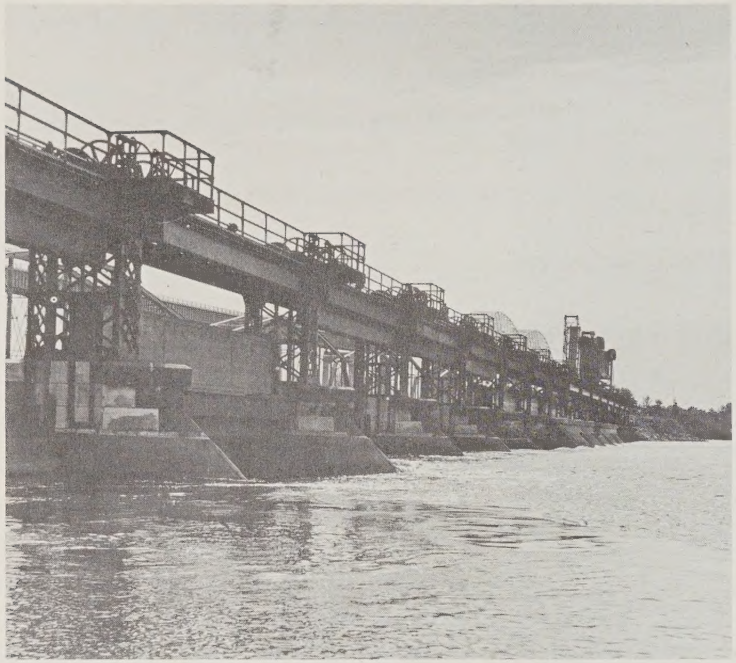
The intensity of shore erosion is increased during periods of high water, causing cliff recession. This poses a severe threat to homeowners along the shores of the Great Lakes.

in part because it is relatively shallow (Figure 2). Here winds have caused differences of about 4 m in water levels between Buffalo and Toledo.

The most obvious changes in the level of a lake are those of the second type, and they are seasonal. All lakes have higher levels in summer than in winter. Although the seasonal variation in all the Great Lakes is less than 0.6 m, in Lake Ontario the maximum difference from a winter low to a summer high may be as great as 1.1 m.

In addition, all the Great Lakes exhibit long-term fluctuations in levels from three and a half to six times greater than the seasonal variations. These long-term fluctuations were known to the Native peoples living along the shores of Lake Ontario hundreds of years ago. They believed that the lake levels rose for seven years and then dropped for the next seven. Today it is realized that these long-term fluctuations affect all the lakes at about the same time and that the intervals between periods of high and low water vary from 10 to 30 years. Just as the seasonal variations do, the long-term fluctuations reflect increases or decreases in the volume of water stored in a given lake.

In each lake the volume of water is dependent upon the amount of precipitation (snow and rain) over the whole lake; the amount of water delivered by rivers, streams, and ground water; the inflow from the lake above; and the inflow from any manmade diversion. Waters are lost from a lake by the counteracting pro-



Structures controlling the discharge of water from Lake Superior into the St. Marys River. Sault Ste. Marie, Ontario, looking towards Sault Ste. Marie, Michigan.

cesses of evaporation; outflow from the lake, either natural or through artificial diversions of water to other drainage basins; and withdrawal for domestic and industrial use.

The amounts of precipitation and evaporation are determined by long-term climatic trends over the entire Great Lakes basin. A single dry spell or rainy season has little effect on lake levels. It is only when precipitation is persistently above average or evaporation below average for a number of years that lake levels are raised significantly. Conversely, they are lowered appreciably only when low precipitation or high evaporation persists over an extended period.

Still under debate is the effect on the lower lakes of varying the discharge from Lake Superior. Since the outflow is controlled at Sault Ste. Marie, it would seem a simple matter either to withhold water or to release it. During the high waters of 1972/73 the discharge through the control structures was reduced, and this did in fact lower the water levels of Lake Michigan, Lake Huron, and Lake Erie, but only very slightly. A similar situation occurred in Lake Ontario. It was hoped that increasing the discharge through the control structures at Cornwall during the same period of high waters would lower the level of Lake Ontario, but again the level was reduced by only a very small amount. The conclusion is that man's ability to control lake levels by means of structures such as those already in place is very limited.

Shore erosion and sedimentation Shore erosion is another natural process operating along the shoreline of a lake. It results from many causes but principally from the breaking of waves on the shore. The extent of the erosion depends on the energy of the waves, the composition of the shore cliffs, the height of the cliffs, and the level of the lake. Erosion is more severe during periods of high water.

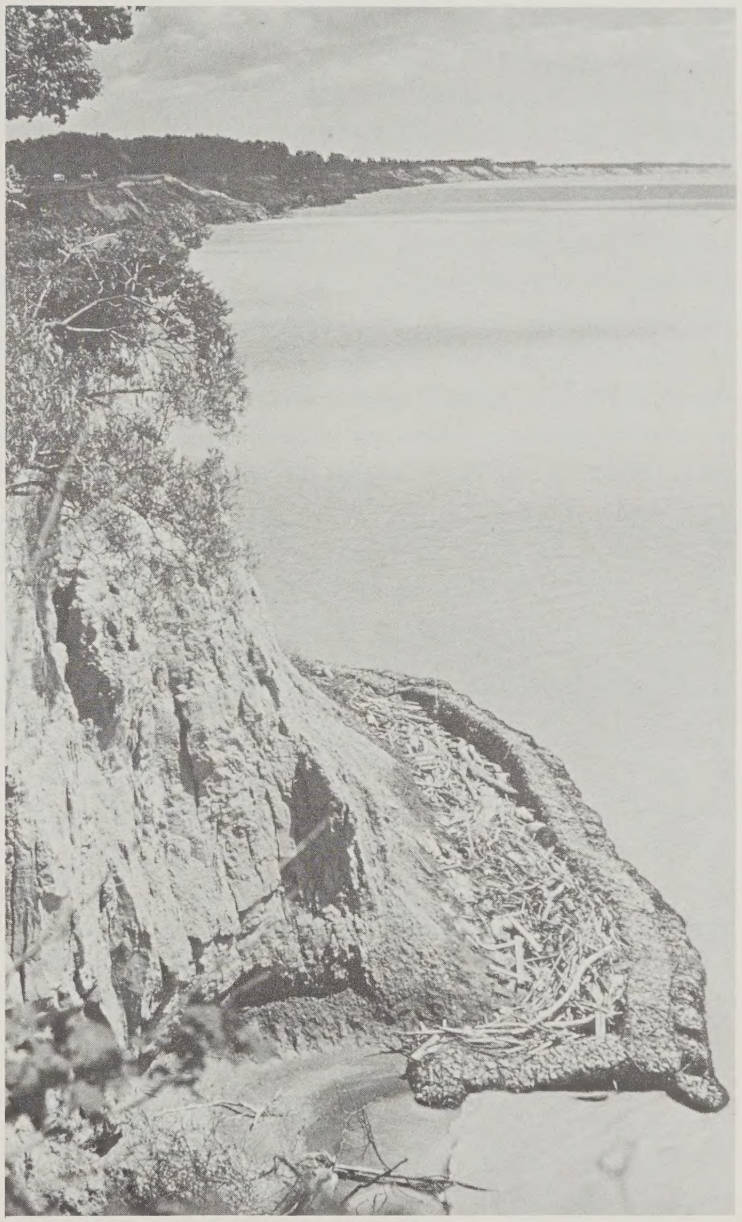
Waves are caused by winds, and the energy they develop is governed by the velocity of the winds, the depth of the water, and the distance the winds and waves travel over open water. Shore cliffs consisting of loosely consolidated sands and clays and exposed to winds and waves that have travelled over great distances suffer the most intense erosion. Shorelines where solid rock is exposed suffer virtually no erosion.

To gain some idea of the volume of material derived from shore erosion and of the damage caused to lakeshore property during periods of high water, the

This rocky shoreline of hard crystalline rocks of the Precambrian Shield suffers very little erosion. Cape Gargantua, Lake Superior Provincial Park.

governments of Canada and Ontario in 1972/73 undertook a joint survey of the Canadian shores of Lake Ontario, Lake Erie, and Lake Huron, and the shores of Georgian Bay. In specific site surveys it was found that the total volume of material eroded from the shores was nearly 20 million cubic metres. One startling statistic was that 81 per cent of this total came from a stretch of only 100 km along the north shore of Lake Erie near Port Burwell.

Waves generally attack a shore at an angle, thus generating a longshore current, which transports most of the coarser sediment—sand and silt—away from the eroding face in a direction parallel to the shores. Some of this material may end up as a beach, a spit, or a baymouth bar, far removed from the eroding site.

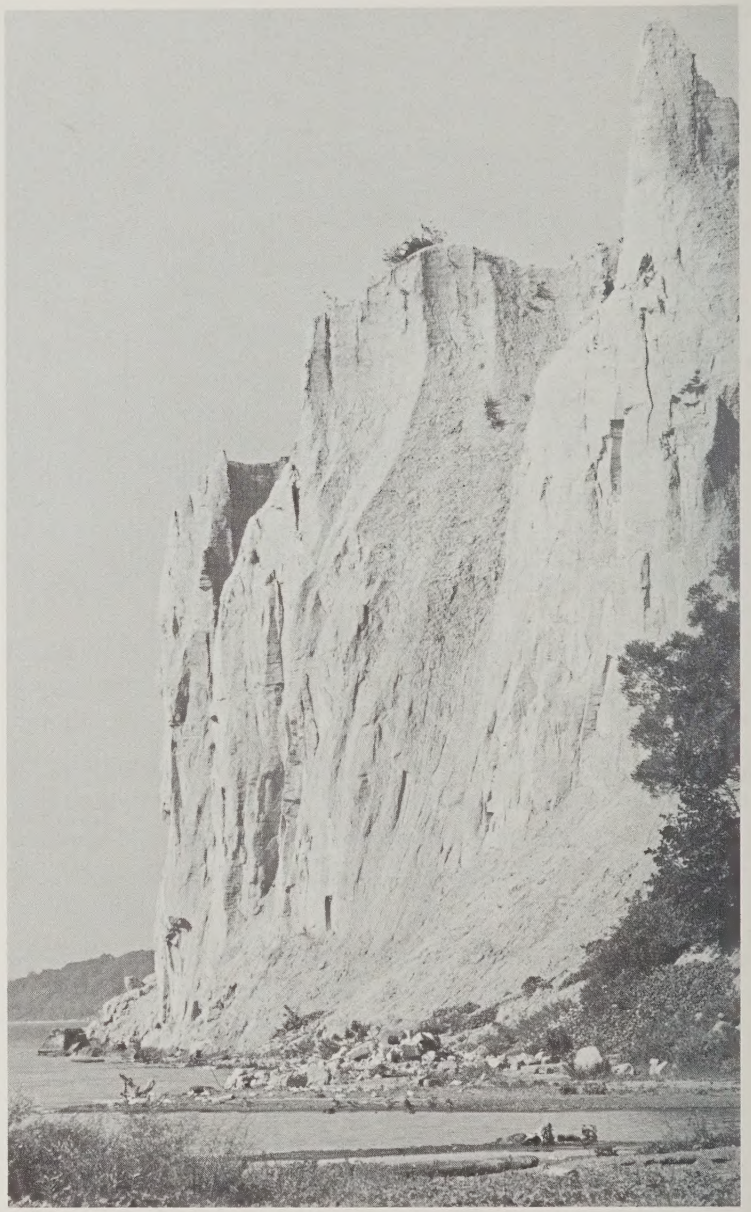


This section of the north shore of Lake Erie east of Port Burwell undergoes severe erosion. Notice the protective structures at the base of the cliff.

Baymouth bars have formed at the mouths of many streams and rivers entering the lakes. There is a large one, the Burlington Bar, at the entrance to Hamilton Harbour. Presque Isle on the south shore of Lake Erie and Long Point on the north shore are large spits. Toronto Island, once a spit attached to the mainland, has been built up over the last 3000 to 5000 years by material from the Scarborough Bluffs to the northeast. The waves of rising waters in the Lake Ontario basin have eroded the Bluffs about 1 km northward to their present position. Today the average rate of erosion of the Bluffs is about 50 cm/yr, and they lose about 300 000 m^3 of sediment annually. Investigations suggest that only 6 per cent of the sediment is carried by the longshore current to end up at Toronto Island; the rest is too fine to be retained in the beaches and is eventually deposited in the deeper parts of the lake.

Shore erosion is just one of the processes providing sediment to the lakes. Rivers and streams discharging into them also deliver heavy loads, and some sediment is airborne. Most of the material ends up at the bottom of the lake receiving the sediment or along its shores, but some is carried into the downstream lake. Sedimentation has been going on ever since the formation of the first proglacial lakes. As a result, the bedrock basins of the individual lakes are for the most part buried under thick accumulations of sands, silts, and clay.

According to recent estimates, Lake Erie and Lake Ontario receive a total of about 23 million tonnes of sediment annually. Of this amount about 35 per cent is brought into the two lakes by rivers and streams, more than half of it in the months of March and April. Sediment carried by streams has undoubtedly increased over the last 200 years as forested lands were converted to agricultural and urban use.



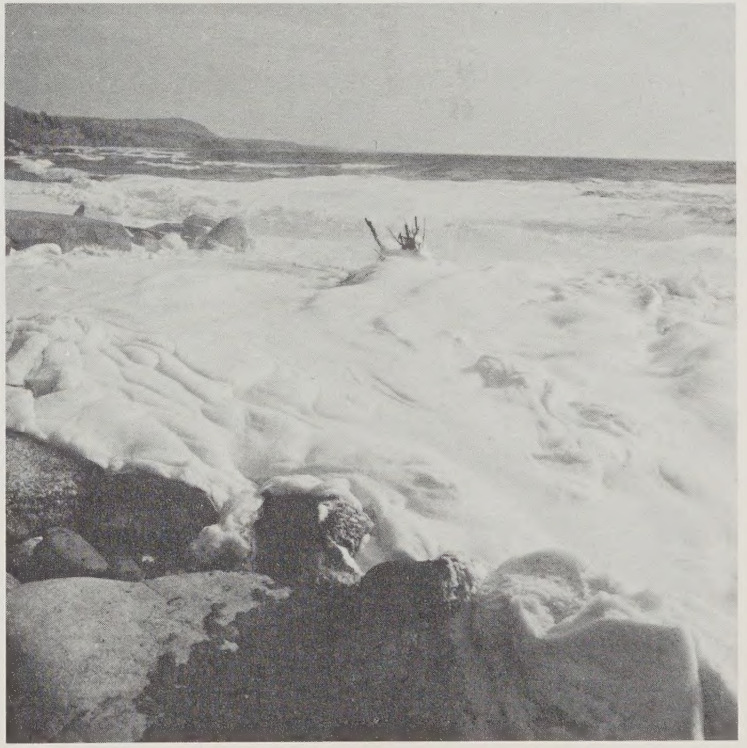
The Needles (formerly called the Dutch Church) on the north shore of Lake Ontario. Bluffers Park, Scarborough Bluffs, Metropolitan Toronto.

Pollution While the accumulation of sediments in all the Great Lakes is a natural process, the increase in sedimentation is causing greater and greater problems. Sediment deposited over the spawning grounds of a fish community can reduce, or even destroy, a species. An estimated $100 million is spent annually in dredging to clear entrances to harbours around the Great Lakes. However, the worst aspect of the increase of sediment to the Great Lakes is the fact that chemical elements such as phosphorus and mercury and chemical compounds such as PCBs (polychlorinated biphenyls) become bonded to the very fine particles of sediment.

Most of the sediment entering a lake is composed of these very fine particles which can remain in suspension for a long time and enter the food chain. While in suspension, they circulate in the lake in response to whatever currents may be present and may pass through the lake to the next one downstream. If they are deposited in shallow water, wave action can disturb them and put them back into suspension.

An example of this sequence of events is given in a recent report of the International Joint Commission known as PLUARG (Pollution from Land Use Activities Reference Group): "A major input to the Great Lakes until 1970 was the industrial discharge of mercury into the St. Clair and Detroit rivers. The sediments and fish in Lake St. Clair became contaminated with mercury . . ." The distribution of this metal in the sediments of Lake St. Clair is demonstrated to be related to the waters that discharge into that lake from the St. Clair River. However, since Lake St. Clair is shallow (maximum depth 6 m), the sediments deposited during periods of calm water can become resuspended when the water is agitated. Thus mercury-contaminated sediments can travel slowly through Lake St. Clair and the Detroit River into Lake Erie. The western and central portions of Lake Erie are also shallow, and so the contaminated sediment moves on through the lake or is deposited in the deep eastern basin where it accumulates in what is called a "permanent sink".

Sediment is of concern because of the several roles it plays in pollution, but it is by no means the only vehicle by which pollutants enter a lake. Many undesirable elements and compounds, and organic matter, may be carried to a lake directly by running water, for example, from an inefficient or overloaded sewage disposal plant or from factories. In addition, many pollutants such as pesticides can enter a lake from the atmosphere.



Industrial pollution, Lake Superior. Marathon, Ontario.

And what of the future?

The early explorers, as they paddled the Great Lakes charting the new continent, were at a loss to explain the vast accumulation of fresh water. Scientific investigations were required to establish the connection between the lakes and continental glaciation. Later, monitoring of the lake levels and the climatic conditions provided an insight into the fluctuating lake levels.

The first European settlements on the Great Lakes were trading posts, some of which became military and naval bases, and the impact of these small communities on the lakes was slight. Over the last two centuries, however, these communities have grown into cities and then into vast urban and industrial complexes. As expansion took place, more and more demands were made on

Toronto Harbour 1820, facing east. (Lithograph facsimile of an original drawing by Sir Peregrine Maitland.)

The Richard L. Hearn Generating Station on Toronto's waterfront was originally coal fired. Conversion to natural gas and a new 215 m stack have reduced pollution in the Metropolitan Toronto area.

the lakes and more and more wastes were poured into them, among them chemical elements such as phosphorus and mercury, and poisonous organic compounds. Eventually pollutants threatened to destroy the lower lakes as a reservoir of fresh water and drastically reduced the fish life in them. Scientists became alarmed and spoke out on the potential destruction of the lakes—and governments heeded their warnings.

In 1909 Canada and the United States signed the Boundary Waters Treaty. In 1972 the two countries concluded the Great Lakes Water Quality Agreement, which led to extensive surveys directed towards determining and monitoring the physical, chemical, and biological conditions of the lakes. In addition, detailed studies of lake levels were undertaken to explore the possibility of controlling the fluctuations. The analysis of the data gathered through these programs and activities provides the factual input for legislation and regulations, which, when implemented, can not only preserve the vital resource but can ensure that it will be of even greater value to the citizens of the Great Lakes basin.

References

Bruce, J. P. and J. W. Giles, *Canada/Ontario Great Lakes Shore Damage Survey.* Ministry of Natural Resources, Toronto, 1975.

Hough, J. L., *Geology of the Great Lakes.* University of Illinois Press, Urbana, 1958.

Kreutzwiser, R., "Might 'management' save Great Lakes' shores?" *Canadian Geographic,* Vol. 97, No. 2, Oct./Nov.

PLUARG, *Environmental Management Strategy for the Great Lakes System.* International Joint Commission, Windsor, 1978.

Prest, V. K., *Quaternary Geology of Canada.* Economic Geology Report Series, Geological Survey of Canada, Ottawa, 1970.

Information sources

The Conservation Council of Ontario
6th Floor, 45 Charles Street East
Toronto, Ontario M4Y 1S2

Great Lakes Basin Commission
P.O. Box 999
3475 Plymouth Road
Ann Arbor, Michigan, 48106

Information Services Branch
Ontario Ministry of Natural Resources
Whitney Block
99 Wellesley Street West
Toronto, Ontario M7A 1W3

International Joint Commission
100 Ouellette Avenue
Windsor, Ontario N9A 6T3

Marine Information Centre
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6

Student activities

1. What factors governed the development of the Great Lakes?
2. The present elevations at selected localities of proglacial Lake Iroquois are shown in Figure 5. Trace this figure and draw contours to illustrate the present slope of the Iroquois water plane (using a 25 m interval), and determine the direction of uplift. The result will be an *isobase* map.
3. When the discharge of Lake Superior waters at Sault Ste. Marie is reduced, the effect on the levels of the lower lakes is slight and takes time to be effective. Suggest reasons for this.
4. Visit the shoreline of one of the present Great Lakes and observe and record the manner in which the shoreline is being eroded, the form of the beach, the beach materials and their distribution, and the effects of the breaking of waves on the shore.
5. How do waves generate a longshore current and how is sediment transported parallel to the shore? Consult a textbook on physical geology.
6. Select an urban centre, large or small, located on the shore of one of the Great Lakes. What factors govern its location and what uses does it make of lake waters?
7. The waters of the Great Lakes and the connecting rivers serve many purposes. Consult references to determine the importance of the following: electrical power development, transportation, recreation, shipping, food supply. Examine the effect of fluctuating lake levels on each of these uses.
8. Determine, through references or local historical sites, the role of the Great Lakes during the War of 1812.

Audio-visual aids

ENCYCLOPAEDIA BRITANNICA EDUCATIONAL CORPORATION
16 mm sound film
The Beach: A River of Sand (20 min)

NATIONAL FILM BOARD OF CANADA
16 mm sound films
1) *Not Man's to Command* (14 min)
2) *Second Frontier* (21 min)
3) *The Rise and Fall of the Great Lakes* (17 min)

Glaciation (multimedia kit): includes overhead projectuals on the development of the Great Lakes with illustrated manual by V. K. Prest.

The Great Lakes, another publication in the new ROM ENCOUNTER SERIES, provides a clear and concise introduction to the formation of the Great Lakes and the physical processes that control fluctuations in lake levels. Shore erosion and sedimentation are discussed and certain aspects of pollution are explained. Excellent maps, diagrams, and photographs accompany the text.

Other books in the series
An Introduction to Ontario Fossils, Janet Waddington
The Niagara River, Walter M. Tovell

Several books now in preparation will focus on other important features of the Ontario landscape.

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